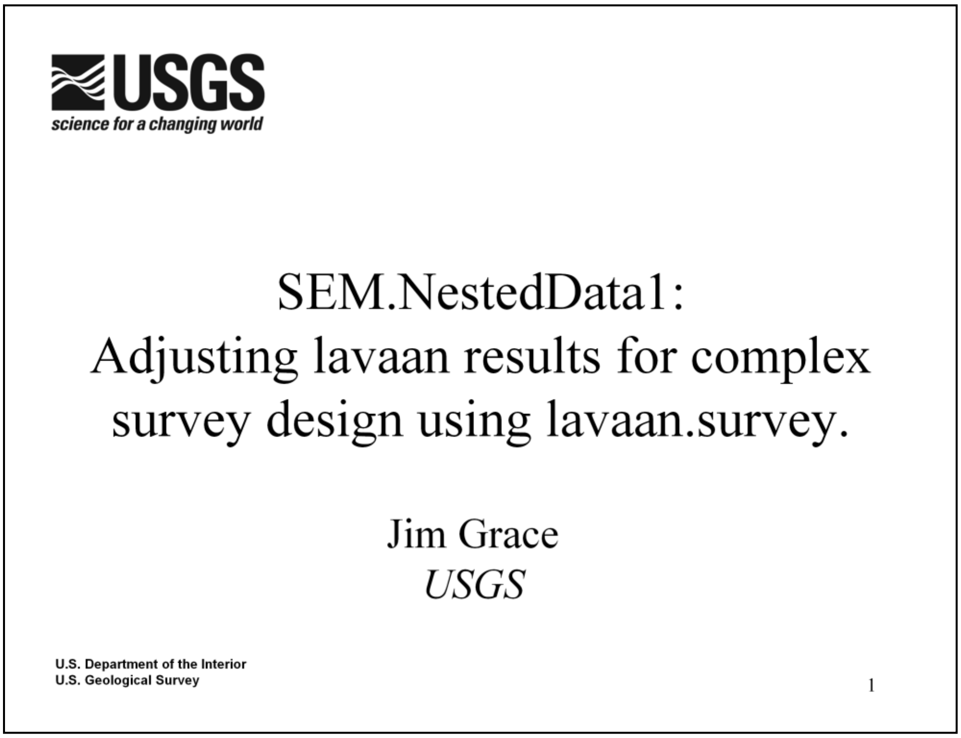

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science for a changing world

SEM.NestedData1: Adjusting lavaan results for complex survey design using lavaan.survey.

Jim Grace
USGS

U.S. Department of the Interior
U.S. Geological Survey

This module addresses an important question, "What should I do when the data are not a simple random sample?" While there are many variations of, and possible approaches to, this problem, here I summarize a simple approach designed for those using the lavaan package for estimating SE models. This approach uses a companion package, "lavaan.survey", which implements an adjustment procedure.

Key reference for this material is:

Oberski, D. 2014. lavaan.survey: An R package for complex survey analysis of structural equation models.

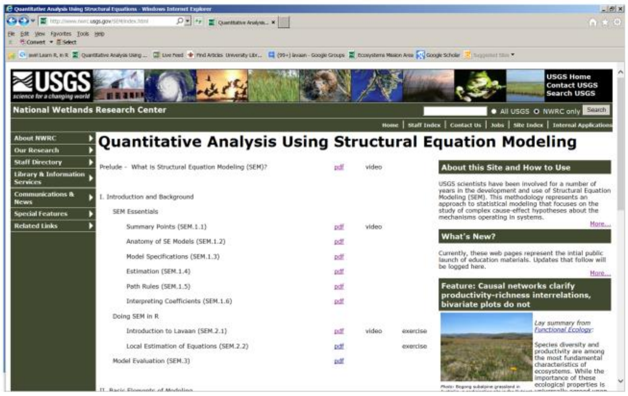
Notes: IP-56512; Support provided by USGS Climate & Land Use R&D and Ecosystems Programs. Thanks to Diann Prosser, Chris Patrick, and other members of the "NOAA Shorelines Group" for input on this tutorial, as well as example data. Formal review of the material from which this tutorial was derived was provided by Jesse Miller and Phil Hahn, Univ. Wisconsin. Any use of trade, form, or product names is for descriptive purposes only and does not imply endorsement by the U.S. Government. Questions about this material can be sent to sem@usgs.gov. Last revised 15.06.18.

A Quick Synopsis

It is possible to adjust lavaan results for data nesting and other complexities using “lavaan.survey”.

Note: if you are not familiar with lavaan objects or need a refresher, go to http://www.nwrc.usgs.gov/SEM and look at tutorial SEM2.1 “Introduction to Lavaan”.

A one-page lavaan refresher is presented on the next page.


Quantitative Analysis Using Structural Equations - Windows Internet Explorer
http://www.nwrc.usgs.gov/SEM/index.html
Quantitative Analysis...
File Edit View Favorites Tools Help
Convert Select
Learn R, in R
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About NWRC
Our Research
Staff Directory
Library & Information Services
Communications & News
Special Features
Related Links

Quantitative Analysis Using Structural Equation Modeling

Prelude - What is Structural Equation Modeling (SEM)?	pdf	video	
I. Introduction and Background			
SEM Essentials			
Summary Points (SEM.1.1)	pdf	video	
Anatomy of SE Models (SEM.1.2)	pdf		
Model Specifications (SEM.1.3)	pdf		
Estimation (SEM.1.4)	pdf		
Path Rules (SEM.1.5)	pdf		
Interpreting Coefficients (SEM.1.6)	pdf		
Doing SEM in R			
Introduction to Lavaan (SEM.2.1)	pdf	video	exercise
Local Estimation of Equations (SEM.2.2)	pdf		exercise
Model Evaluation (SEM.3)	pdf		
II. Basic Elements of Modeling			

About this Site and How to Use

USGS scientists have been involved for a number of years in the development and use of Structural Equation Modeling (SEM). This methodology represents an approach to statistical modeling that focuses on the study of complex cause-effect hypotheses about the mechanisms operating in systems.

More...

What’s New?

Currently, these web pages represent the intial public launch of education materials. Updates that follow will be logged here.

More...

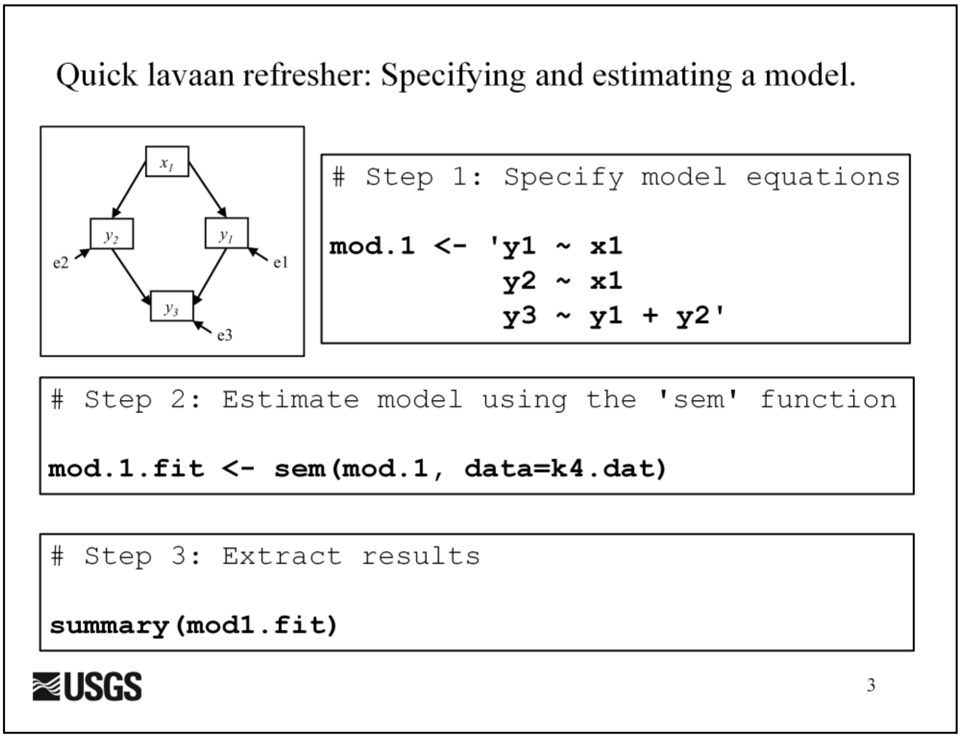
Feature: Causal networks clarify productivity-richness interrelations, bivariate plots do not

Lay summary from Functional Ecology:

Species diversity and productivity are among the most fundamental characteristics of ecosystems. While the importance of these ecological properties is

Photo: Bogong subalpine grassland in

Briefly, lavaan.survey is designed to work with lavaan objects. lavaan is an R package that implements classical “global-estimation” approaches to SEM. My website has a bit of information on modeling with lavaan, as well as links to additional resources.



Quick lavaan refresher: Specifying and estimating a model.

x1
y2
y1
y3
e2
e1
e3

```
# Step 1: Specify model equations

mod.1 <- 'y1 ~ x1
          y2 ~ x1
          y3 ~ y1 + y2'
```

```
# Step 2: Estimate model using the 'sem' function

mod.1.fit <- sem(mod.1, data=k4.dat)
```

```
# Step 3: Extract results

summary(mod1.fit)
```

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This is slide 6 from "SEM.2.1-Intro to Lavaan – version 1.0".

Note: there are some preliminary steps, of course.

(1) You need the variables that are in the model included in a data object, which in this example is named "k4.dat".

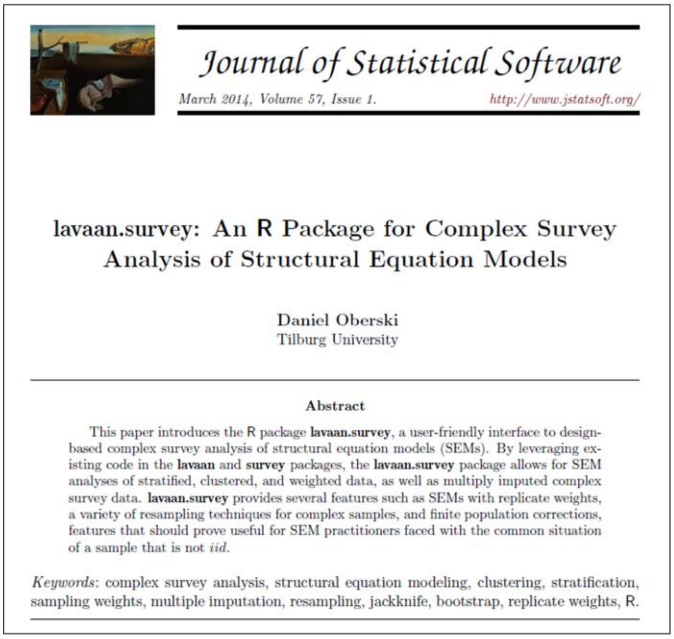
(2) You need to load the lavaan library

```
# Load lavaan library
library(lavaan)
```

Regarding this slide:

1) Specifying a model simply involves an equation for each response variable in the model.
2) The "sem" function is used to "fit" the model. This process creates a "fit object", in this case "mod.1.fit" that contains numerous results.
3) You can extract some of the main results from the fit object using the "summary()" function.

What is “lavaan.survey”?



Journal of Statistical Software

March 2014, Volume 57, Issue 1. http://www.jstatsoft.org/

lavaan.survey: An R Package for Complex Survey Analysis of Structural Equation Models

Daniel Oberski
Tilburg University

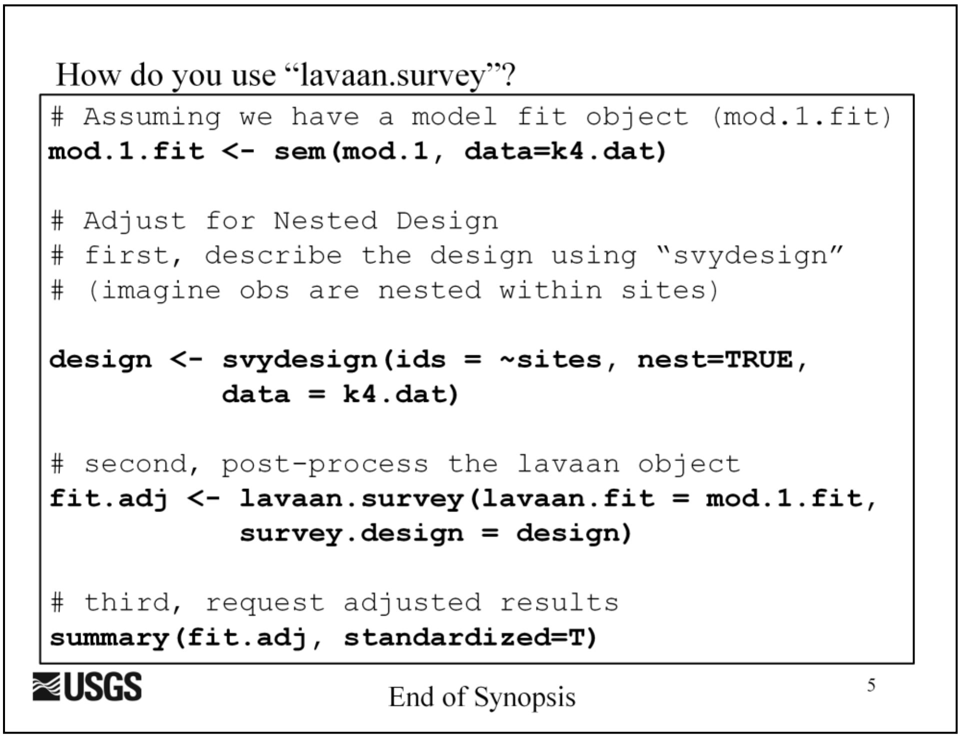
Abstract

This paper introduces the R package **lavaan.survey**, a user-friendly interface to design-based complex survey analysis of structural equation models (SEMs). By leveraging existing code in the **lavaan** and **survey** packages, the **lavaan.survey** package allows for SEM analyses of stratified, clustered, and weighted data, as well as multiply imputed complex survey data. **lavaan.survey** provides several features such as SEMs with replicate weights, a variety of resampling techniques for complex samples, and finite population corrections, features that should prove useful for SEM practitioners faced with the common situation of a sample that is not *iid*.

Keywords: complex survey analysis, structural equation modeling, clustering, stratification, sampling weights, multiple imputation, resampling, jackknife, bootstrap, replicate weights, R.

Direct link to the paper can be found at

http://www.jstatsoft.org/v57/i01/paper



How do you use “lavaan.survey”?

```
# Assuming we have a model fit object (mod.1.fit)
mod.1.fit <- sem(mod.1, data=k4.dat)

# Adjust for Nested Design
# first, describe the design using “svydesign”
# (imagine obs are nested within sites)

design <- svydesign(ids = ~sites, nest=TRUE,
          data = k4.dat)

# second, post-process the lavaan object
fit.adj <- lavaan.survey(lavaan.fit = mod.1.fit,
           survey.design = design)

# third, request adjusted results
summary(fit.adj, standardized=T)
```

End of Synopsis

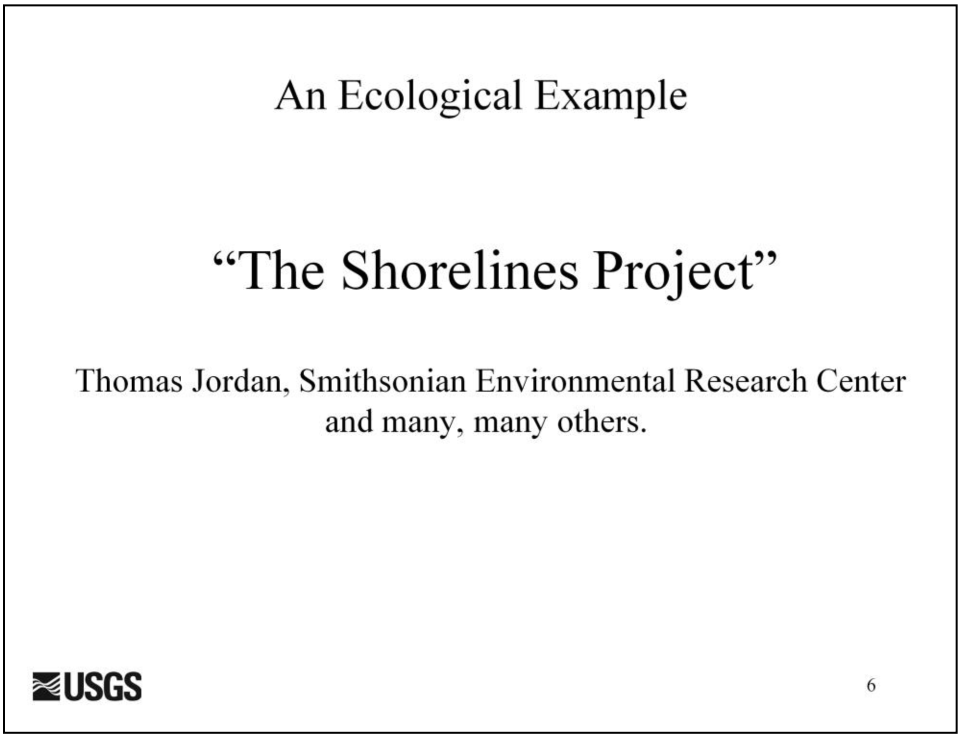
5

Remember, before using any R package, you need to load it. So,

```
# Load lavaan.survey library
library(lavaan.survey)
```

There are additional commands we can use for extracting results from a post-processed object. For example,

```
fit.adj  # gives chi-square
modindices(fit.adj) # extracts mod indices
resid(fit.adj, type="standardized") # resids
```

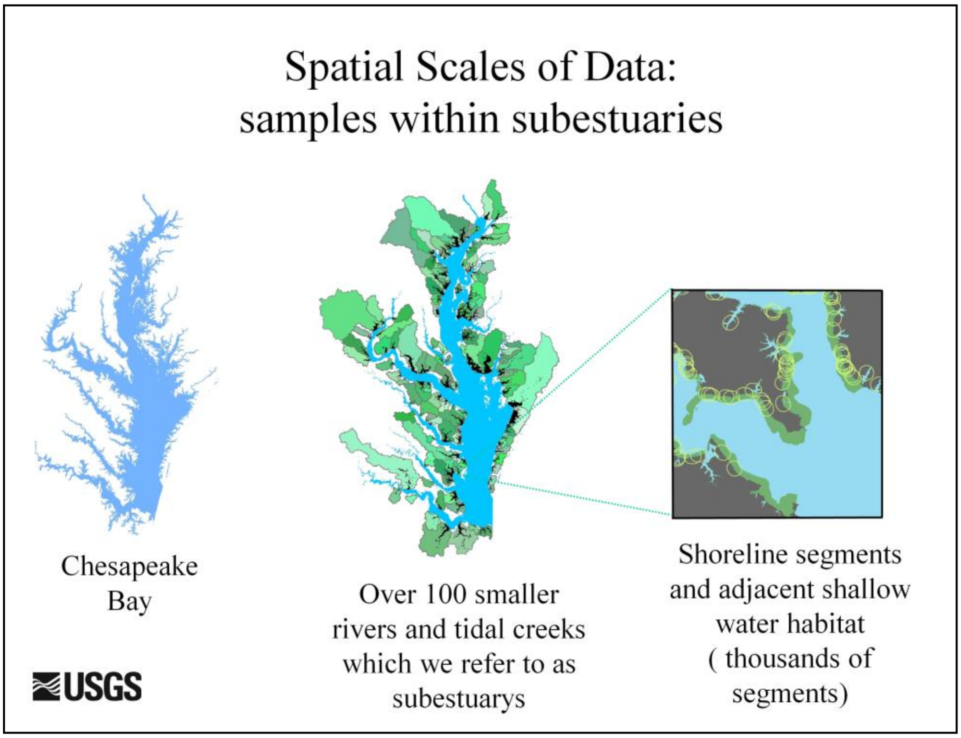


An Ecological Example

"The Shorelines Project"

Thomas Jordan, Smithsonian Environmental Research Center
and many, many others.

Special thanks to the Shorelines Project folks for suggesting this tutorial and for providing the modeling questions and associated data.



Spatial Scales of Data: samples within subestuaries

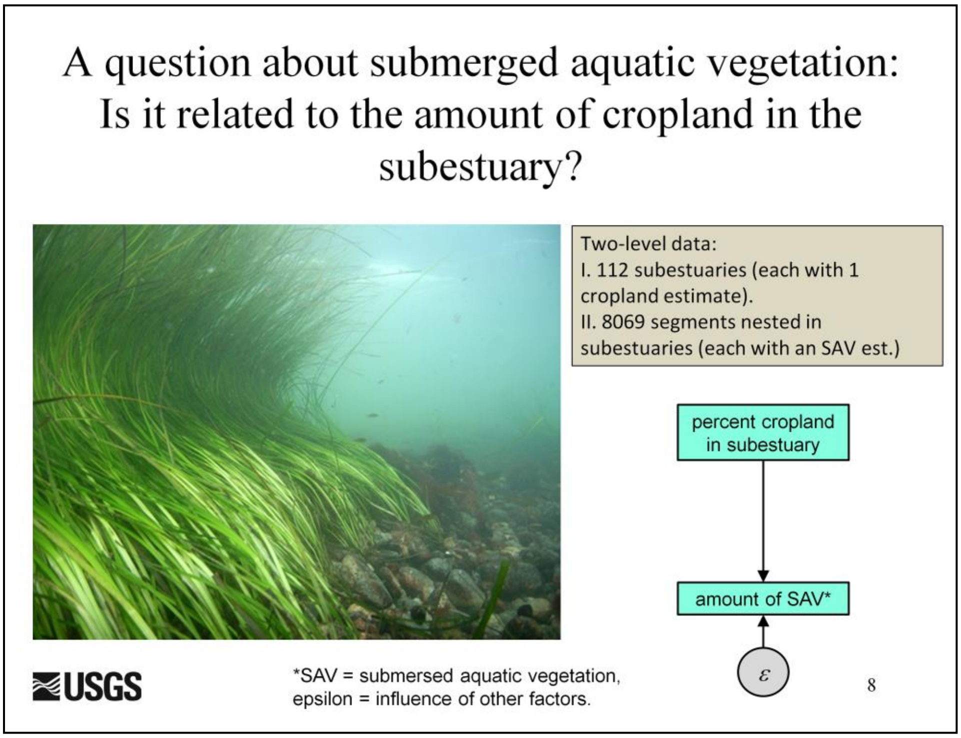
Chesapeake Bay

Over 100 smaller rivers and tidal creeks which we refer to as subestuarys

Shoreline segments and adjacent shallow water habitat (thousands of segments)

Here is a slide from a presentation given by Chris Patrick, Smithsonian Environmental Research Center. This illustrates the conceptual hierarchy of samples being collected at locations that fall within larger spatial units, “subestuaries”.

As far as nesting effects goes, this is perhaps one of those cases where the grouping variable, “subestuary” may or may not impose a major grouping effect on the sample. It behooves us to consider this as cluster sampling, nonetheless.



A question about submerged aquatic vegetation: Is it related to the amount of cropland in the subestuary?

Two-level data:
I. 112 subestuaries (each with 1 cropland estimate).
II. 8069 segments nested in subestuaries (each with an SAV est.)

percent cropland in subestuary

amount of SAV*

ε

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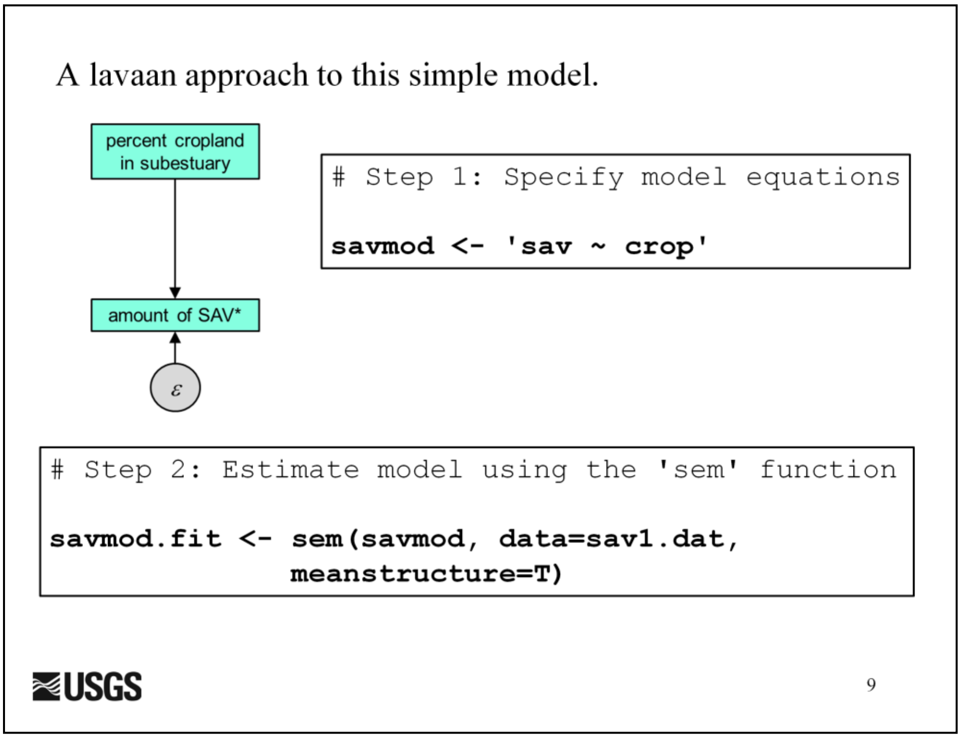
*SAV = submersed aquatic vegetation,
epsilon = influence of other factors.

More about the sav research can be found in:

Patrick, C.J., Weller, D.E., Li, X., and Ryder, M. 2014. Effects of Shoreline Alteration and Other Stressors on Submerged Aquatic Vegetation in Subestuaries of Chesapeake Bay and the Mid-Atlantic Coastal Bays. Estuaries and Coasts.



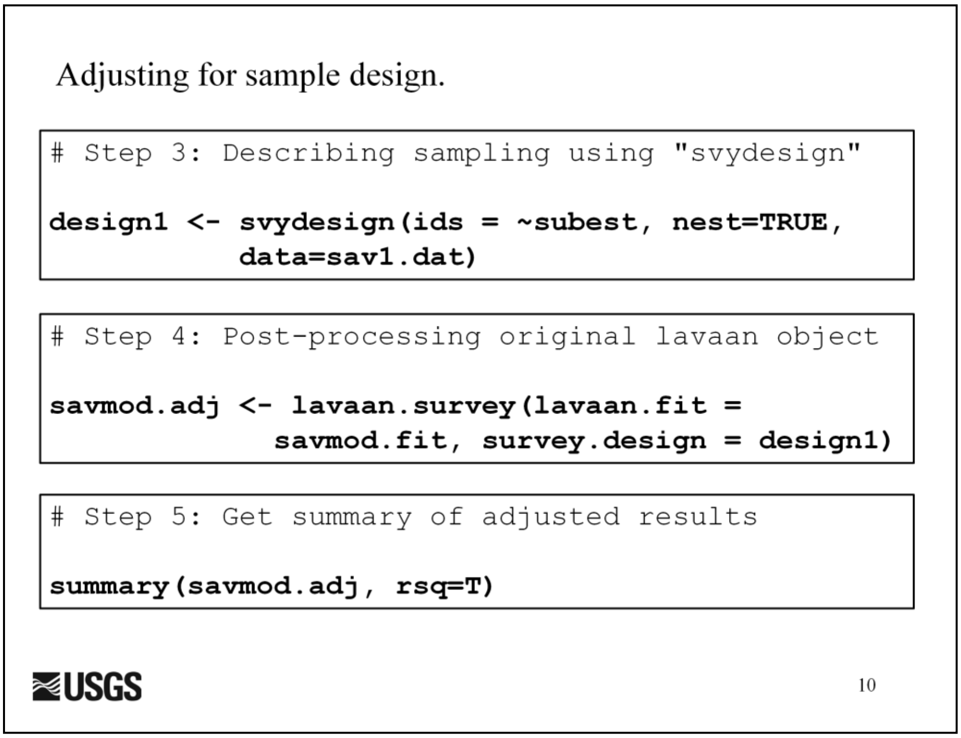
A lavaan approach to this simple model.

percent cropland in subestuary
amount of SAV*
ε

```
# Step 1: Specify model equations

savmod <- 'sav ~ crop'
```

```
# Step 2: Estimate model using the 'sem' function

savmod.fit <- sem(savmod, data=sav1.dat,
              meanstructure=T)
```

Note that this code is in the R file “SEM.NestedData_code.R”.



Adjusting for sample design.

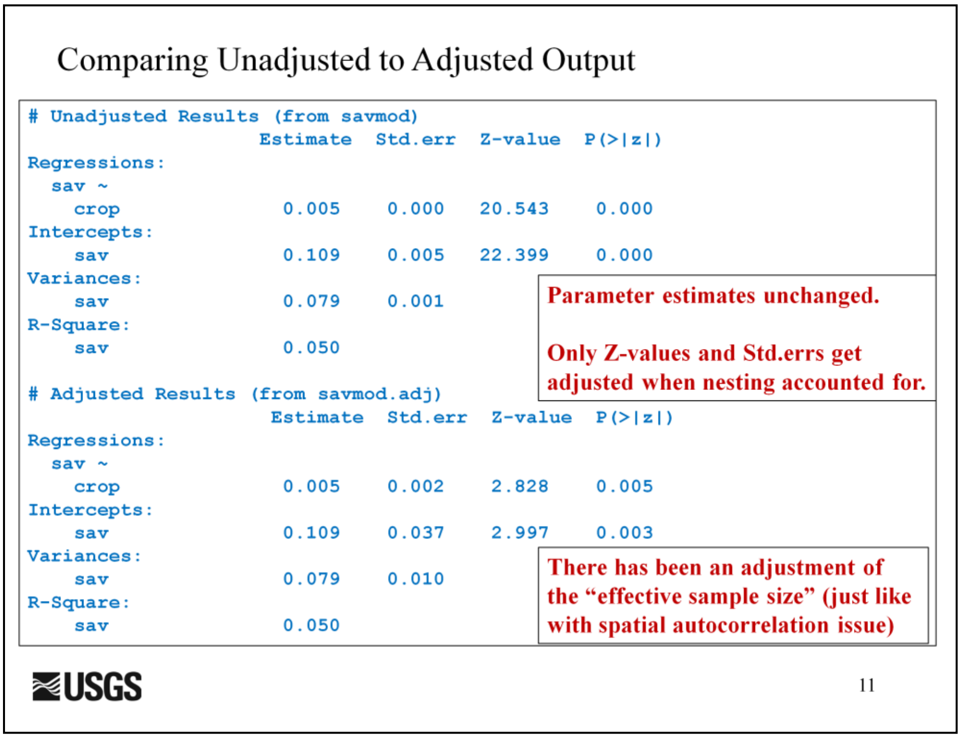
```
# Step 3: Describing sampling using "svydesign"

design1 <- svydesign(ids = ~subest, nest=TRUE,
           data=sav1.dat)
```

```
# Step 4: Post-processing original lavaan object

savmod.adj <- lavaan.survey(lavaan.fit =
             savmod.fit, survey.design = design1)
```

```
# Step 5: Get summary of adjusted results

summary(savmod.adj, rsq=T)
```

A key step in the adjustment process is to describe the sampling design for lavaan.survey to use. There are lots of possibilities and one should consult Oberski (2014) to understand the greater range of potentials for this function. Here we have the simplest case, samples are nested within “subest” (subestuaries).

Once we have the design described, we use it in the “lavaan.survey” function.



Comparing Unadjusted to Adjusted Output

```
# Unadjusted Results (from savmod)
                    Estimate  Std.err  Z-value  P(>|z|)
Regressions:
  sav ~
    crop              0.005    0.000   20.543    0.000
Intercepts:
    sav               0.109    0.005   22.399    0.000
Variances:
    sav               0.079    0.001
R-Square:
    sav               0.050

# Adjusted Results (from savmod.adj)
                     Estimate  Std.err  Z-value  P(>|z|)
Regressions:
  sav ~
    crop              0.005    0.002    2.828    0.005
Intercepts:
    sav               0.109    0.037    2.997    0.003
Variances:
    sav               0.079    0.010
R-Square:
    sav               0.050
```

Parameter estimates unchanged.

Only Z-values and Std.errs get adjusted when nesting accounted for.

There has been an adjustment of the "effective sample size" (just like with spatial autocorrelation issue)

Here I first show results returned by the command:

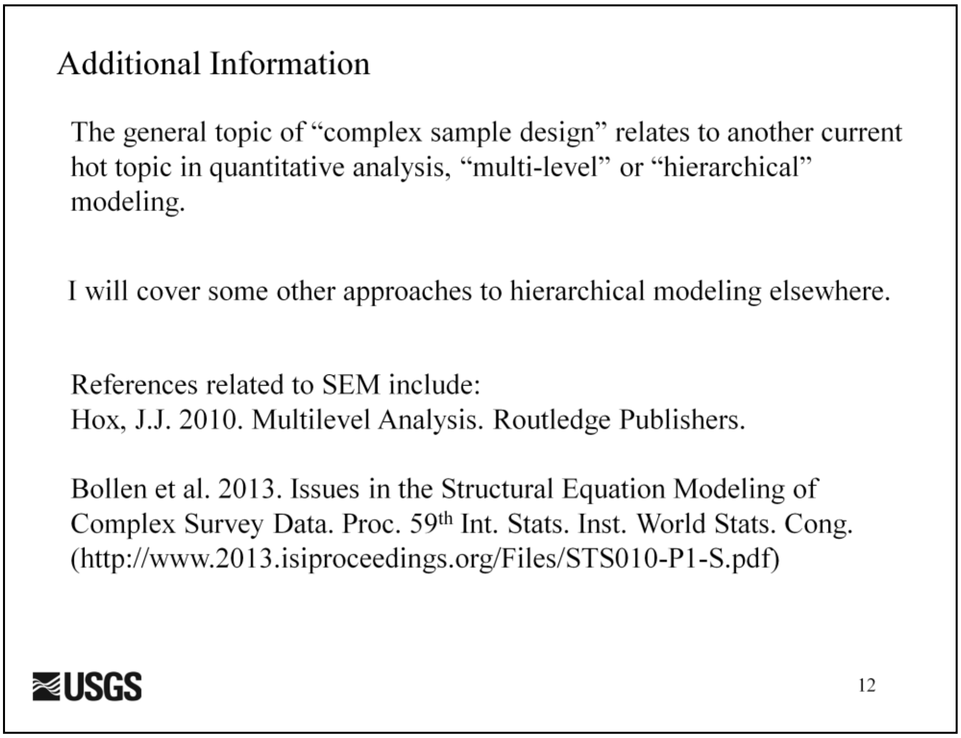
`summary(savmod, rsq=T)`

I don't show the model fit statistics in this case because the model is saturated and, thus, fit is not computed.

Comparing the unadjusted results to the adjusted ones obtained by

`summary(savmod.adj, rsq=T)`

is interesting. Note that the parameter estimates are unchanged for this case (no unequal weighting of samples). What is very different is the standard errors, which are much bigger after adjustment. The reason? Nesting creates non-independence in the data and one effect of that is an effective sample size that is much smaller than the actual sample. This issues is also found with spatial autocorrelation.



Additional Information

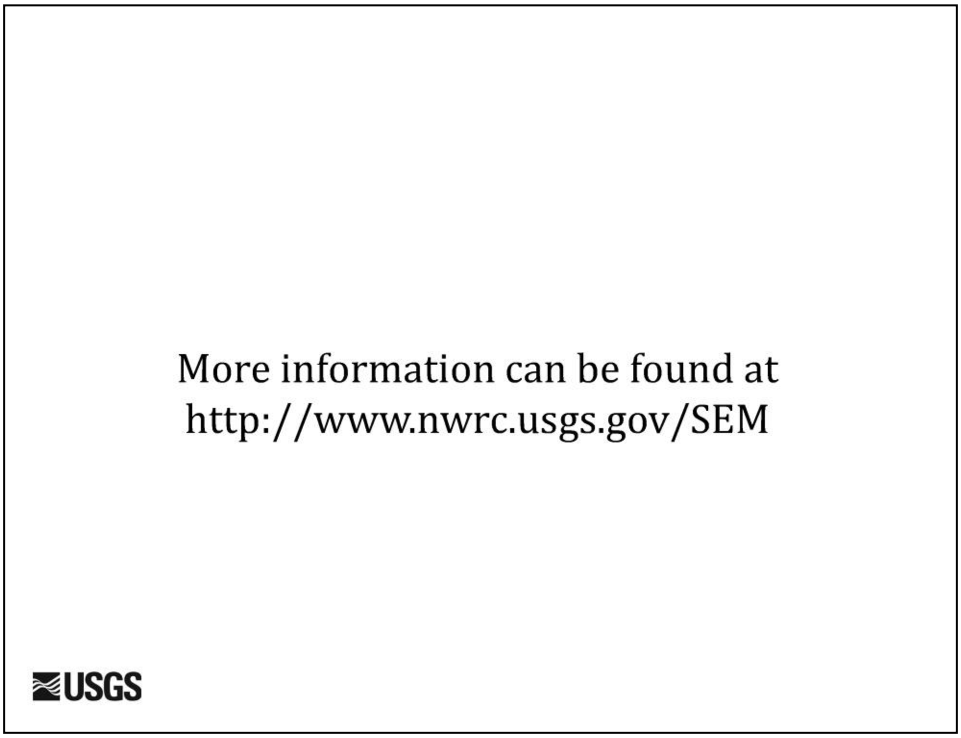
The general topic of “complex sample design” relates to another current hot topic in quantitative analysis, “multi-level” or “hierarchical” modeling.

I will cover some other approaches to hierarchical modeling elsewhere.

References related to SEM include:
Hox, J.J. 2010. Multilevel Analysis. Routledge Publishers.

Bollen et al. 2013. Issues in the Structural Equation Modeling of Complex Survey Data. Proc. 59th Int. Stats. Inst. World Stats. Cong. (http://www.2013.isiproceedings.org/Files/STS010-P1-S.pdf)

Here, my treatment of the subject is very brief. More information can be found in Bollen’s paper. Beyond that, there is a large literature on this topic.



More information can be found at
http://www.nwrc.usgs.gov/SEM

I hope this overview has been useful. For more information, go to our webpage or search for examples involving your subject of interest. Questions and comments can be sent to sem@usgs.gov. Please note I cannot guarantee responses to individual inquiries, but will try to incorporate suggestions in future tutorials. – Thanks!